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CLIMATE OF BINGHAMTON, N. Y., SHOWN BY THE HISTOGRAM METHOD.

By JOHN R. WEEKS, Meteorologist.

[Weather Bureau Office, Binghamton, N. Y., Feb. 28, 1921.]

SYNOPSIS.

The histogram method of depicting features of local climate has attracted little attention, but is valuable and deserves wide application. When proper methods of computation are used it not only illustrates features of climate clearly and concisely, enabling many questions to be answered, but it aids in forecast study by separating out from the mass of obscuring data days and periods that present recurrent anomalies, so that the cause of such departures may be ascertained, studied in detail, and perhaps forecast.

The histograms (frequency polygons) presented with this paper are numerous and each contains within itself the data for the entire period of 30 years, showing by the height of each column of the polygon the per cent of times that each variate has occurred. Special features are briefly discussed. The influence of snow cover in causing a double mode in the minimum temperature of December, January, and February, especially prominent in January and giving rise to popular belief in a "January thaw," and again in directing a skew of the curves in February and March toward 32°, is pointed out. Variations in daily cloudiness and precipitation and in 8 a. m. humidity from month to month present interesting features. An anomaly in the monthly precipitation at certain stations in January, February, March, and April for the past 75 to 100 years is mentioned for discussion at some other time.

INTRODUCTION.

The histogram method of statistical research has been so little used in meteorology and climatology that we do not find in the Meteorological Glossary of the British Meteorological Office, for example, either the word "histogram," its equivalent "frequency polygon," or the word "mode," corresponding to the German "scheitelwert" (most frequent number of times that an event is found to occur). Hann in his *Klimatologie* (1) and again in his *Meteorologie* (2) in a discussion of *scheitelwerte* based on insufficient and manifestly limited and incomplete data, condemns the use of the mode in meteorology and climatology, but the objections he raises can with equal validity be applied to the mean. It is true the mode requires greater labor and skill to obtain than does the mean, but is it not of nearly equal importance in general and may it not be of greater importance when biological questions are under consideration? It has been of wide service in other sciences. The histogram goes a step farther in including all the data. With the latter a curve of frequency distribution is obtained. that in some cases corresponds to the normal probability curve of mathematics and may be stated by a mathematical formula.

The mathematical phases of the subject have been ably discussed by Marvin (3) and Tolley (4) in the MONTHLY WEATHER REVIEW. The present article illustrates practical application of the method, without the use of mathematics, as well as its usefulness in answering questions of climate, and, not the least, in bringing to light and permitting the cause to be determined with comparative ease, of anomalies in temperature, rainfall, and other weather elements.

Binghamton is located in latitude 42° 6′ north and longitude 75° 55′ west, at the junction of the Chenango and Susquehanna Rivers, with an altitude above mean sea-level of 870 feet. The surrounding country is "hilly," the hills rising to altitudes of 1,300 to 1,800 feet above sea-level and being dissected by many creeks and ravines. They are composed of slate rock and covered with glacial soil. In a radius of 30 miles there are 75,000 acres of forest. Varied crops are grown, including tobacco, hops, cabbage, beans, potatoes, fruit of all hardy kinds, especially apples, but the principal agricultural product is milk, of which the county marketed $1,750,000 worth in 1919. Large factories of wide reputation occupy scattered portions of the valley, one concern producing $75,000,000 worth of shoes in 1920, but the city is not in any way congested and the city heat and smoke do not affect the climatic records. One-third the population of the United States is within 300 miles. The drainage area of about 4,000 square miles slopes from north to south and is fan-shaped with the city at the handle of the fan. The weather data are homogeneous, taken with standard instruments and exposure, the latter remaining practically the same for the entire period.

The histograms have not been smoothed save those of the daily temperatures and the monthly ranges of temperature. These it has been necessary to correct by means of the formula $\frac{a+2B+c}{4}, \frac{b+2C+d}{4}$, etc., because, in recording the data, decimals were discarded to the nearest degree, giving the halfway decimal to the *even* number, thus causing *even* numbers to predominate in a given ratio. (5) The necessity of a formula to remove this unevenness could have been avoided by using classes of 2° or 4° instead of 3°, but one class seemed too narrow and the other too wide, a class of 3° being best. The formula is perfectly satisfactory.

Each histogram contains within itself all the observations of the 30 years and the height of each column represents the number of times each class was observed during that period. The scale is stated in percentages of the total number of observations in the histogram because percentages are usually desired, and, furthermore, because stating the results in percentages on a uniform scale removes the inequality between histograms containing different numbers of observations, those of January and February, for example, and makes them directly comparable. To obtain the number of observations in each column, instead of the per cent, all that is necessary is to multiply the total number of observations in the histogram by the per cent in the column. One must learn to think of these figures as frequency polygons and not mere illustrative diagrams such as are sometimes used to depict monthly amounts of rainfall, wind velocities for certain periods, etc.

Those who wish to use the method can save much time and labor and insure the accuracy of count that is essential by following a definite system. The writer prefers the use of 13-to-the-inch cross-section paper in sheets of 8 by 10 inches for classifying and counting the variates, as illustrated on a reduced scale in figure 1. Distinctive marks are used to distinguish different periods of years, or different record books, etc., and the accuracy of the count is checked by separate summations of the marks used as the work proceeds. These sheets, after the count is complete, can be made of further use in forecast study, and lines have been added to the illustration that show how this is done from year to year. Certain days will be found that seem peculiar; for example, January 7 of figure 1. Some hold that the cause is recurrent and physical, though as yet not determined. Others hold that it is accidental and due to chance combinations of the weather elements on the days in question. Whatever may be the cause, the histogram method enables such days to be separated from the rest and studied individually. Again, when the frequency distributions of separate weeks or periods are compared, or separate series of years, widenings and contractions of the distribution and shifts of the mode are found that afford fascinating visions of periods and cycles, but must be allotted to chance unless physical reasons for them can be discovered. Unfortunately, from a forecast standpoint, one or the other of two views must be assumed. If the conditions are due to physical laws and are cyclic or recurrent, then we must forecast one thing or one way. But if the conditions are due to chance combinations of weather elements for the day in question, then we must seek out, if possible, the particular combination and forecast accordingly the opposite. In other words, if *chance* has caused the distribution on one particular day or days to lie to one side of the normal frequency polygon for that period, then the probability is that further events will tend to the opposite side of the polygon, and forecasts would be pointed that way. On the other hand, if the shift toward the right or the left is due to *physical causes*, then the forecast should be pointed in the same direction as the shift, and *not* in the *opposite direction.*

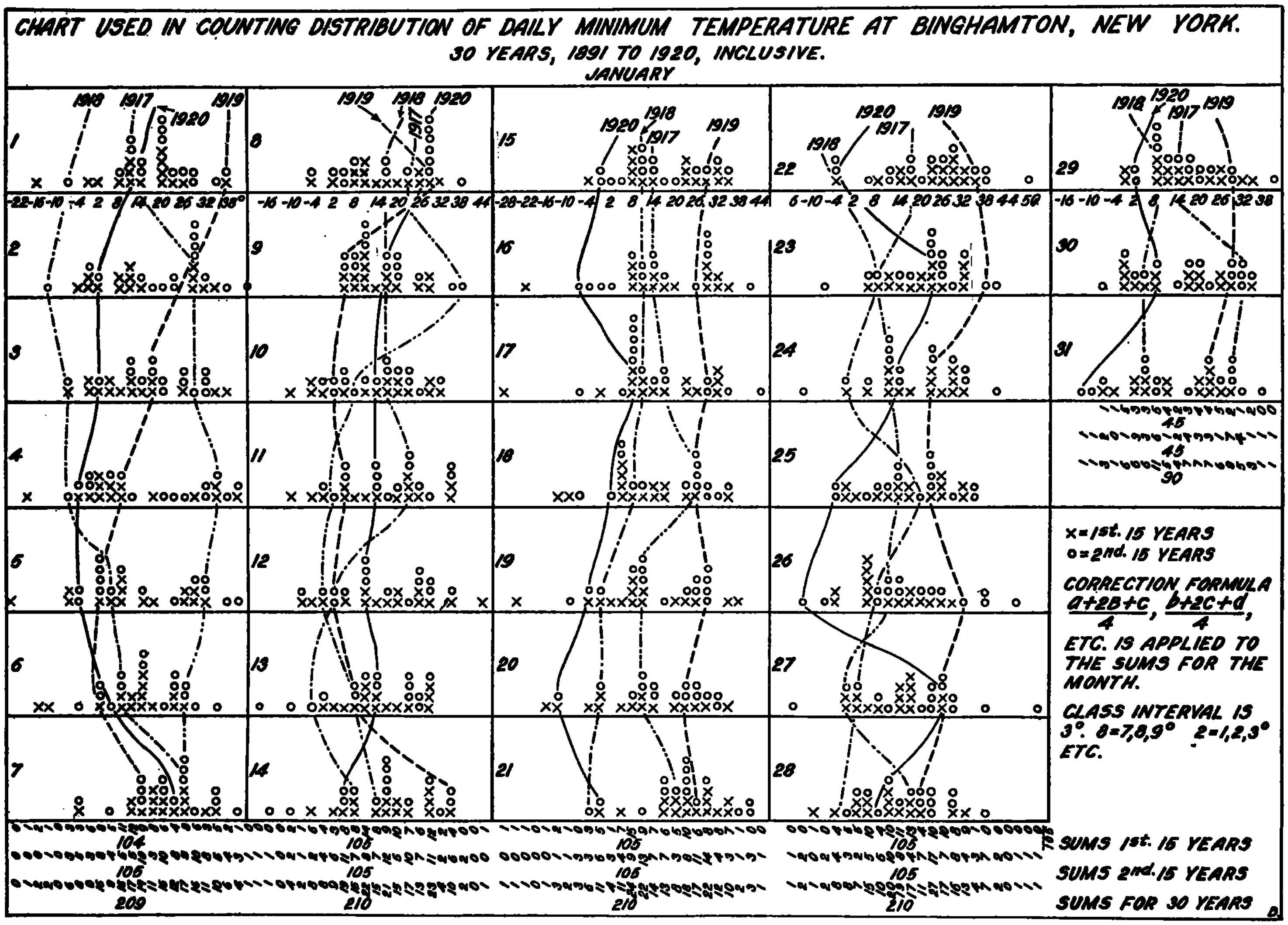


FIG. 1.—Illustrating how the count of variates is made and summed and its further use in forecast study. Original size, 8 by 10 inches.

Nothing will take the place of the daily weather maps, but the use of probabilities has some value in weather forecasting (6).

The histograms can be reproduced by milliograph, tracing, and solar printing, or chalk plate printing. For solar printing the positive print paper supplied for draftsmen has much better keeping qualities before use than blue-print paper. Much of the lettering on the tracings can be done with a typewriter, a heavily inked black ribbon or a carbon-paper ribbon "20 pound" being used, and the tracing paper backed with carbon paper with *face forward*. This makes a print equal to India ink and photo-engraves well. I find the millimeter cross-section paper best for drawing the histograms, or 20-to-the-inch cross-section paper may be used, both of which can be obtained printed on tracing paper, or if on heavy paper it may be made transparent after the drawing is complete with the fluid furnished draftsmen for the purpose.

However much the days and weeks and shorter periods of years may vary among themselves and thus afford material for study, the monthly and annual modes based upon a sufficient number of years are as permanent, com-

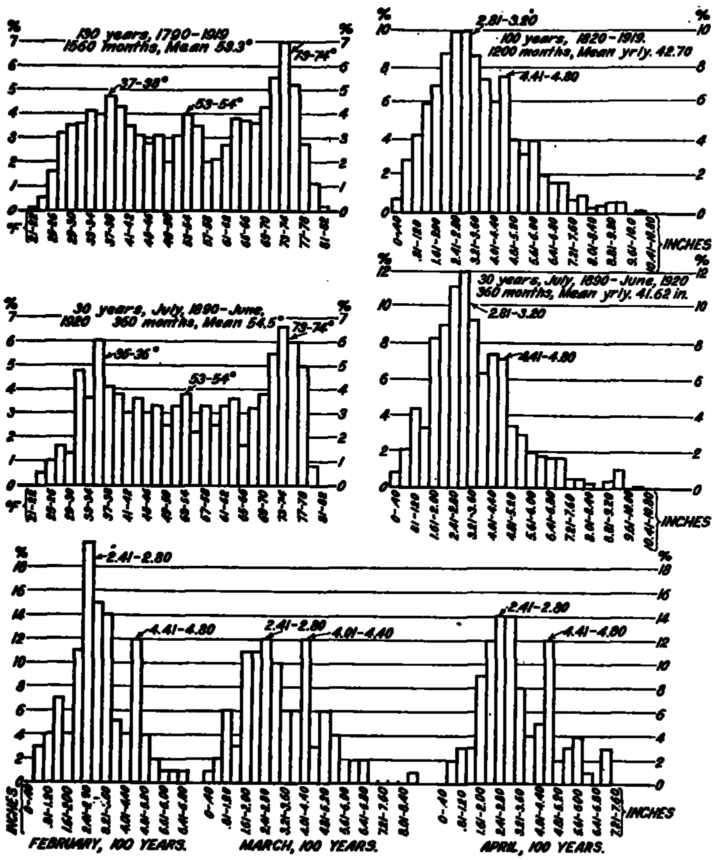


FIG. 2.—Frequency distribution at Philadelphia of monthly mean temperature for 130 and 30 years and monthly precipit tion for 100 and 30 years, illustrating the persistence of the modes.

paratively speaking, as the means for the same period and afford additional valuable information. Figure 2 illustrates this feature of the method and shows further how anomalies in the data are brought out. Note the two modes of monthly precipitation at Philadelphia for February, March, and April of the past 100 years. Similar modes appear in the monthly precipitation at Boston, New York, New Orleans, San Francisco, and other stations. What is more surprising, the higher mode is the same at New Orleans, Philadelphia, and Boston, and the lower mode is the same at Philadelphia and New Orleans. The modal amounts of precipitation, however, do not occur in the same years at each of these stations. At New Orleans a double mode appears in September, October, and November, due to tropical disturbances in those months.

Turning now to the Binghamton histograms, figures 3, 4, 5, 6, 7, and 8, the discussion must be brief and they will be permitted, in the main, to speak for themselves.

In April, May, June, July, August, December, January, and February, the mode of daily maximum temperature, figures 3 and 4, is higher than the mean, and in September, October, November, and March it is lower. In September and October this result is doubtless associated with fogs, and in March with melting snow and ice. The "skew" in February is to the right toward 32° F. and in March to the left toward 32° F., the melting point of snow and ice. The daily minimum temperature is largely a radiation effect, and so in December, January, and February, when there is alternation between bare ground and snow cover, there is a corresponding tendency to two modes, suppressed in December and February and prominent in January. The higher mode in January lies near 32° F. and gives rise to popular belief in a "January thaw." A tabulation of the weather elements of January days with 26° and 11° F. minimum temperature (omitted here) shows that snow cover, not wind direction, as some have supposed, is the effective factor in causing the lower mode and bare ground the higher. (See Table 1.) The daily mean temperature is simply a composite of the daily maximum and minimum temperatures and merits no special comment.

TABLE 1.—*Relation of weather to the modes of minimum temperature for the month of January, 1906–1920, at Binghamton, N. Y.*

	Mode.	
	25°-27° F.	9°-11° F.
Number of times	32	35
Snow on ground:		
Average depth at 8 p. m. ...inch	0.7	2.5
Days with trace or less	16	2
Days with 0.5 inch or less	25	12
Precipitation (mt. to mt.):		
Days with	18	23
Days without	14	12
Cloudiness (during daylight):		
Days cloudy	22	18
Days partly cloudy	7	13
Days clear	3	4
Wind, prevailing direction (mt. to mt.):		
N. ...days	0	3
NE	3	5
E	5	5
SE	2	1
S	4	1
SW	3	6
W	8	5
NW	12	12
At time of minimum temperature:		
Occurrence at midnight	19	18
Occurrence not at midnight	13	17
Average wind velocity ...mi. hr.	6	5
Wind direction—		
N. ...occurrences	0	6
NE	5	6
E	8	7
SE	1	2
S	4	1
SW	4	1
W	4	8
NW	6	4
Average relative humidity at 8 a. m. ...per cent	76	87

The daily maximum wind velocity, figures 5 and 6, shows throughout most of the year a dominant mode at 13 miles per hour, which assumes special prominence in July, the month of thunderstorm frequency (fig. 7). This mode is doubtless a combined friction and viscosity effect conditioned on elevation and topography and suggests that each station may have a distinctive mode due to these factors. (7) The double mode of maximum wind velocity in August and September, the months of least average velocity, southwest and north, corresponds to the trend of the river valleys.

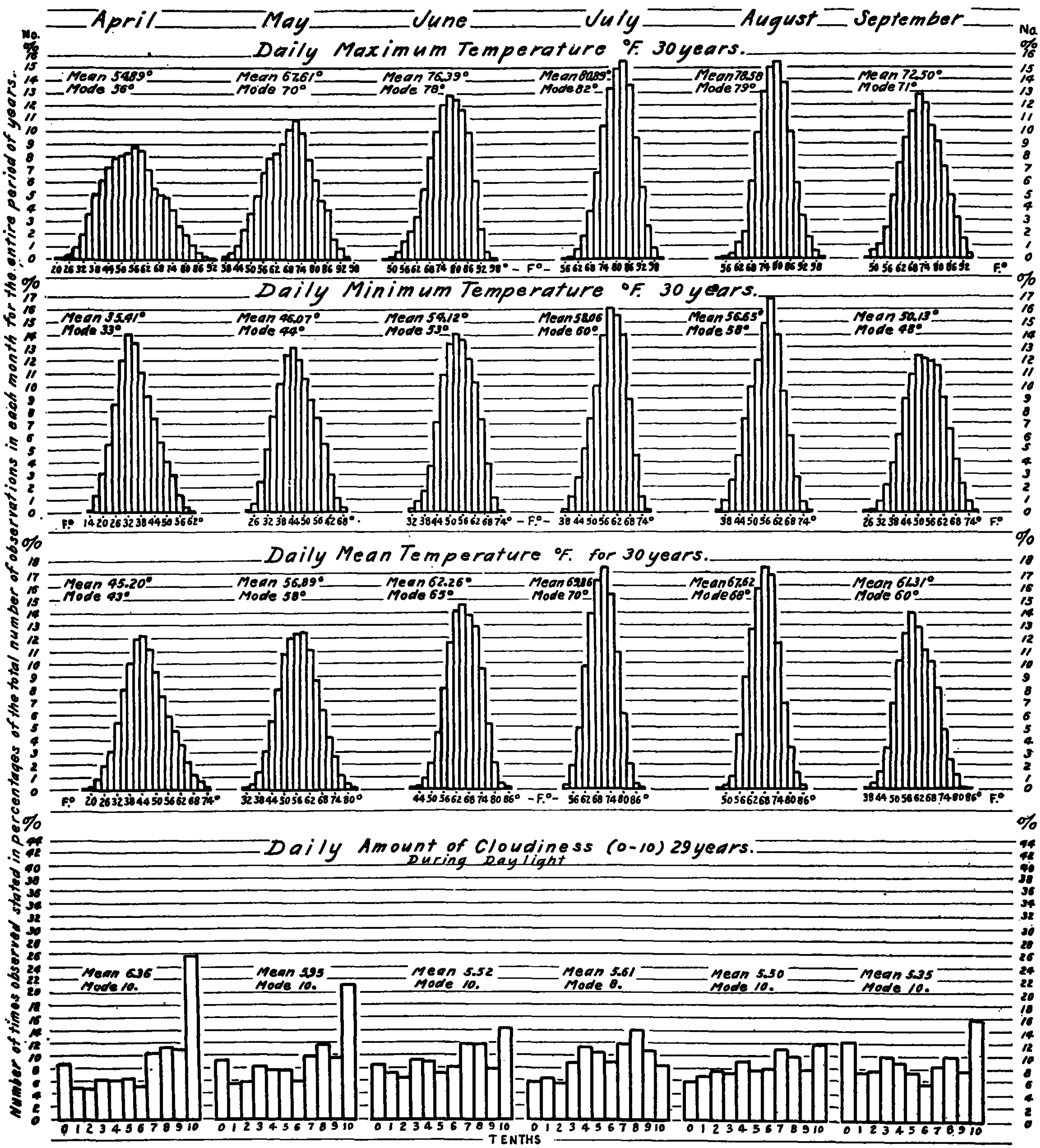


FIG. 3.—Frequency distribution of daily maximum, minimum, and mean temperature and daytime cloudiness at Binghamton, N. Y., April to September, inclusive.

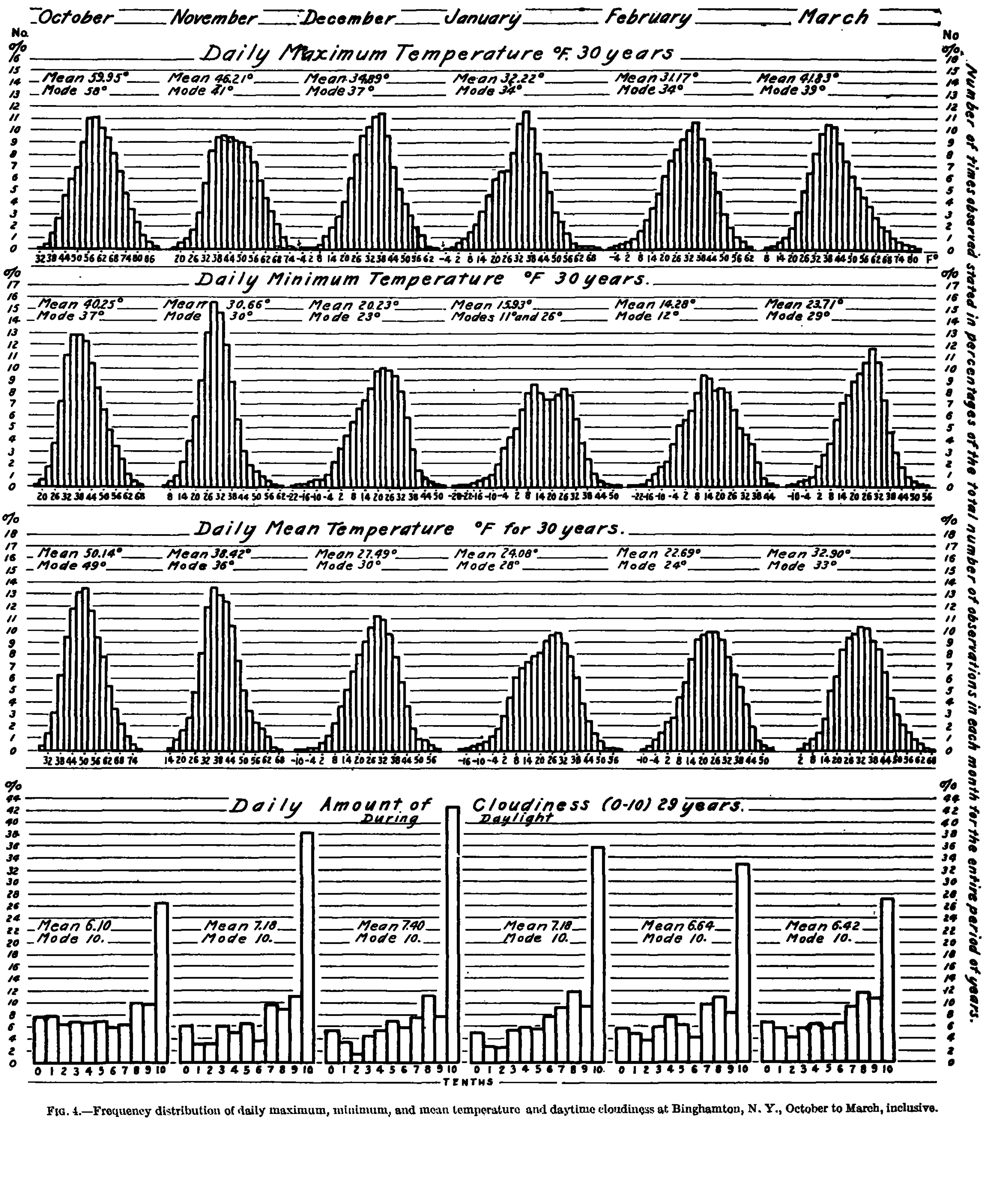


FIG. 4.—Frequency distribution of daily maximum, minimum, and mean temperature and daytime cloudiness at Binghamton, N. Y., October to March, inclusive.

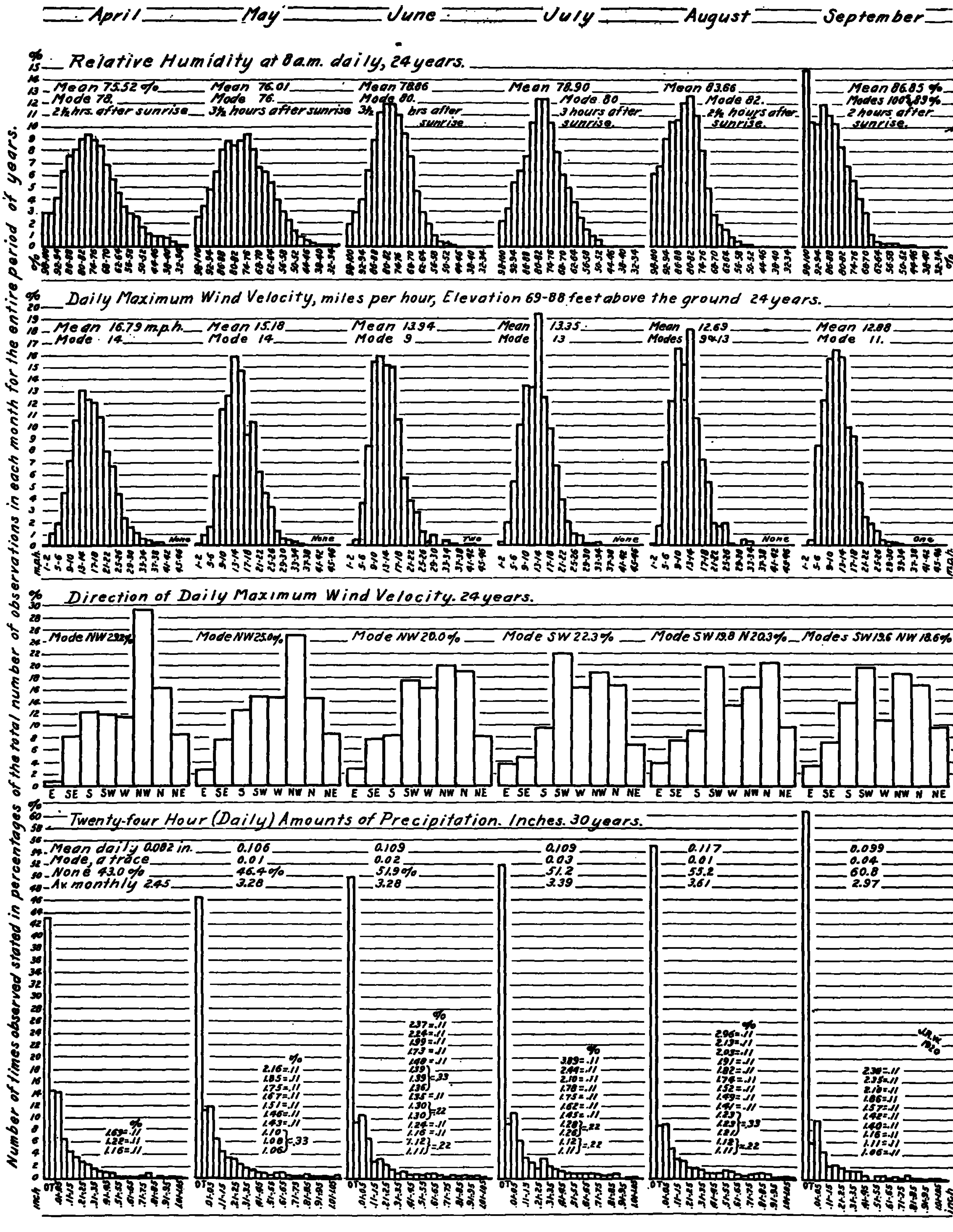


FIG. 5.—Frequency distribution of daily relative humidity at 8 a. m., daily maximum wind velocity and direction, and daily precipitation at Binghamton, N. Y., April to September, inclusive.

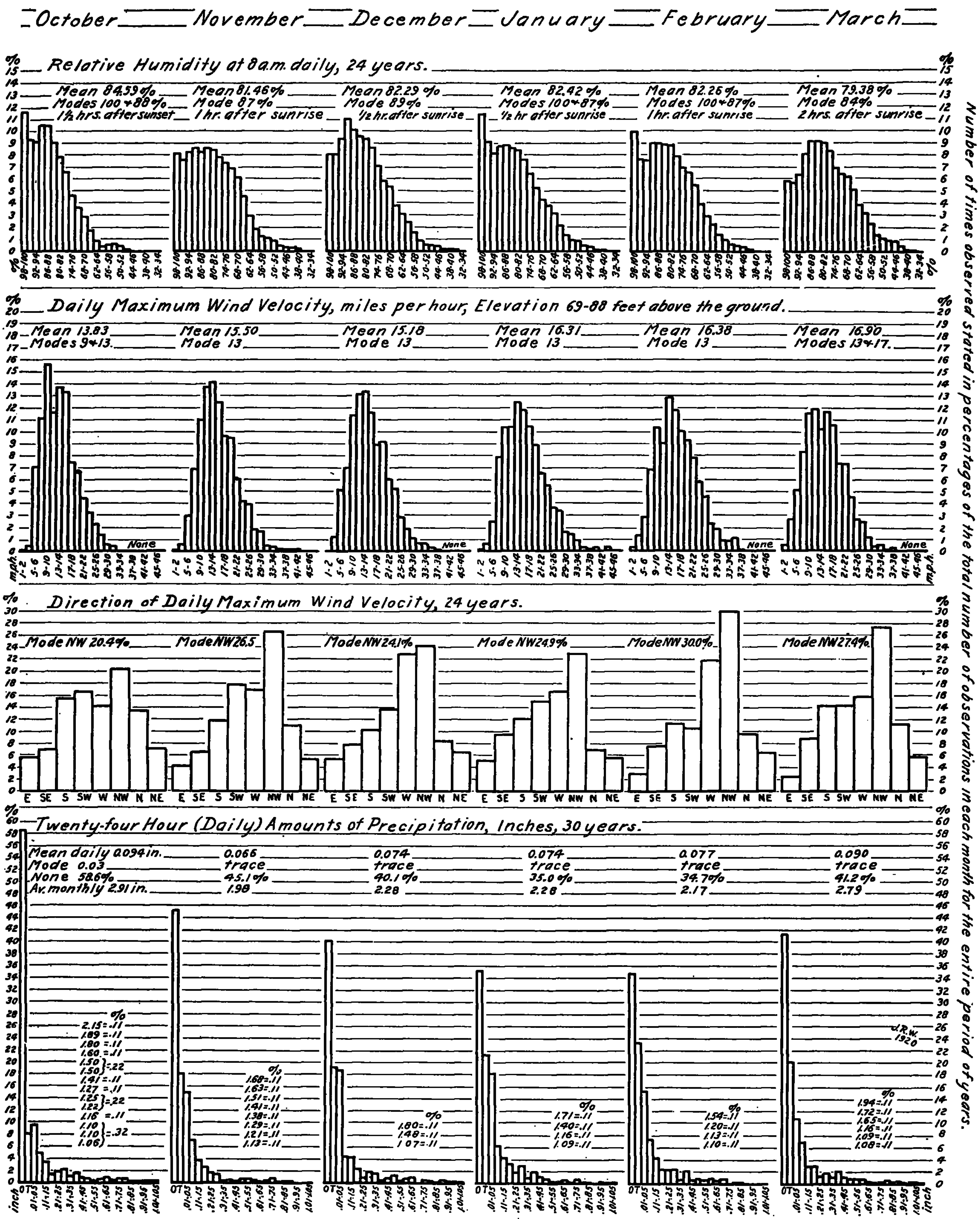


FIG. 6.—Frequency distribution of daily relative humidity at 8 a. m., daily maximum wind velocity and direction, and daily precipitation at Binghamton, N. Y., October to March, inclusive.

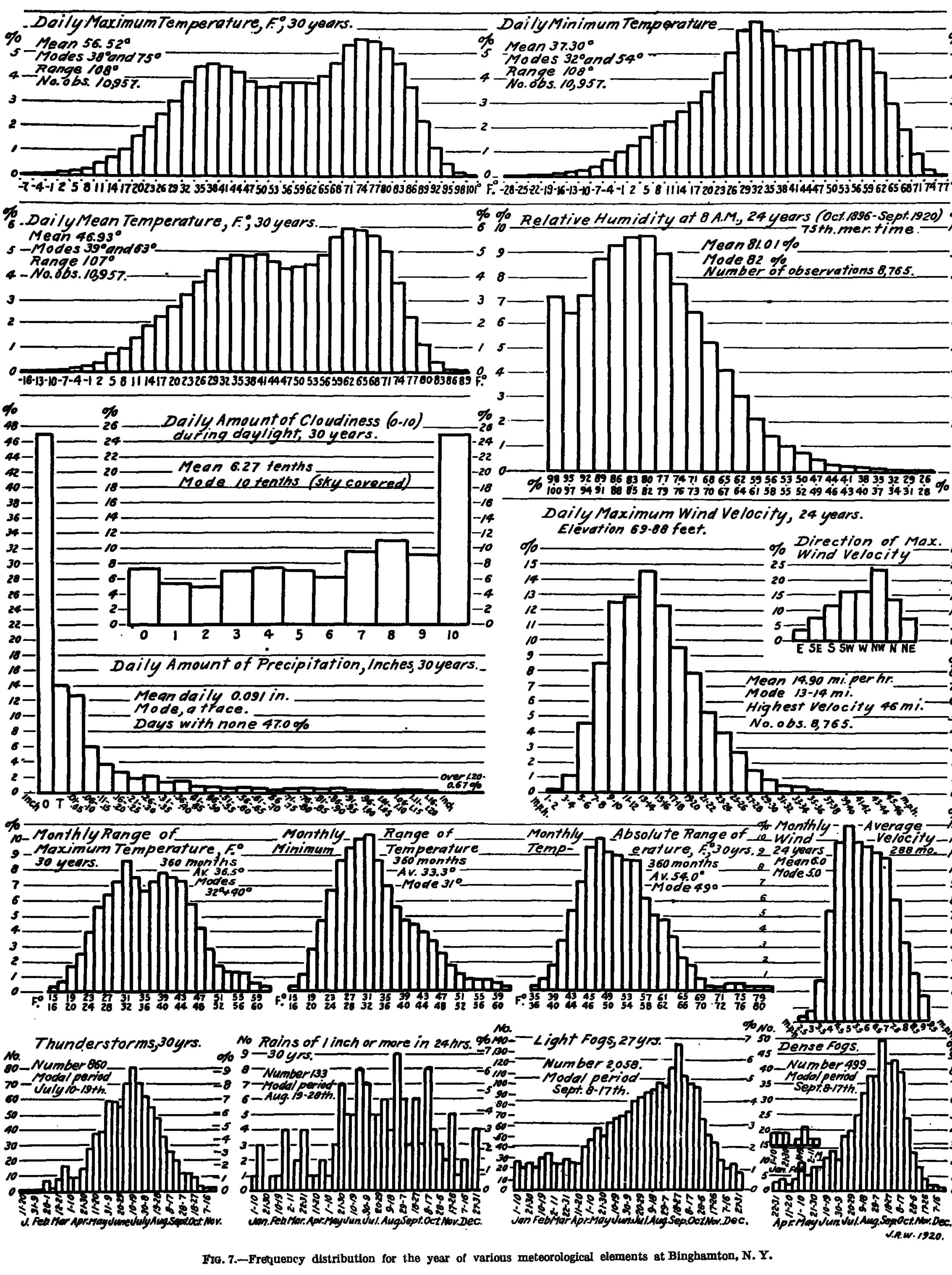
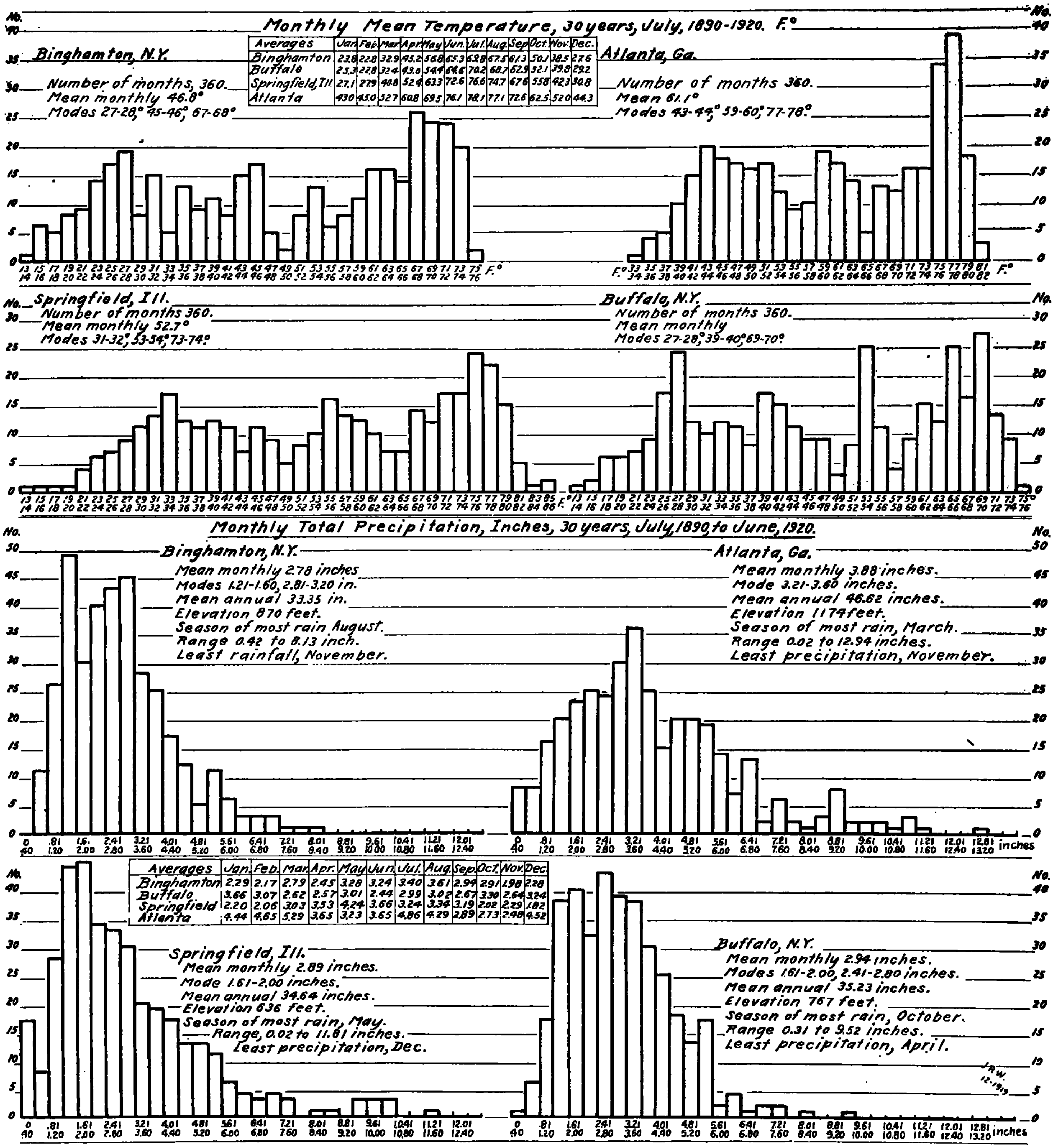


FIG. 7.—Frequency distribution for the year of various meteorological elements at Binghamton, N. Y.



Averages	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Binghamton	23.8	22.8	32.9	45.2	56.8	65.3	69.8	67.5	61.3	50.1	38.5	27.6
Buffalo	25.3	22.8	32.4	43.0	54.4	64.6	70.2	68.7	62.9	52.1	39.8	29.2
Springfield, Ill.	27.1	27.9	40.8	52.4	63.3	72.6	76.6	74.7	67.6	55.8	42.3	30.8
Atlanta	43.0	45.0	52.7	60.8	69.5	76.1	78.1	77.1	72.6	62.5	52.0	44.3

Averages	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Binghamton	2.29	2.17	2.79	2.45	3.28	3.24	3.40	3.61	2.99	2.91	1.98	2.28
Buffalo	3.66	3.07	2.62	2.57	3.01	2.44	2.99	3.02	2.67	3.30	2.64	3.24
Springfield	2.20	2.06	3.03	3.53	4.24	3.66	3.24	3.34	3.19	2.02	2.29	1.82
Atlanta	4.44	4.65	5.29	3.65	3.23	3.65	4.86	4.29	2.89	2.73	2.48	4.52

FIG. 8.—Frequency distribution of monthly mean temperature and monthly total precipitation for 30 years at Binghamton, N. Y., Springfield, Ill., Atlanta, Ga., and Buffalo, N. Y.

The humidity at 8 a. m., figures 5 and 6, presents curious variations. Although 60 per cent of September days, the highest number of any month, are without rain, yet 15 per cent of the days, the highest number of any month, have a humidity at 8 a. m., *two hours after sunrise*, of 98 to 100 per cent. This is due to the prevalence of fogs in that month, the fogs, in turn, being caused by the prevalence of clear nights with diminished temperature. (Fig. 7.) The modal period for dense fog is September 8 to 17. The humidity then diminishes to November, the "Indian summer" month, and increases again with the formation of snow cover in December. It is rather surprising to find the mode for 8 a. m. humidity in January and February to be 98 to 100 per cent. The high humidity occurs on mornings of "radiation" cold and is often accompanied by rime and fog. It is unfortunate that data of daily maximum and minimum humidity are not available.

The smooth curve marked by the tops of the columns of no precipitation, figures 5 and 6, is interesting, as is also the variation in the number of days with a trace. In summer traces of precipitation tend to evaporate before they reach the ground. In winter traces are prominent in the form of snow flurries. The curve of days with no precipitation shows inverse relation to that of days with 10 tenths clouds, or sky entirely overcast, figures 3 and 4. A peculiar feature of the latter is that any decrease in the number of overcast days is divided rather evenly among the days with lesser amounts of cloudiness, the number of entirely clear days remaining fairly constant throughout the year, though greatest in September. Since 1905, or for 15 years of the 29, the daily amount of cloudiness has been determined by observations every two hours of the amount, kind, and direction of movement of the clouds.

Figure 7 shows the annual distribution of the different daily weather elements. The two modes of maximum, minimum, and mean temperature are due to the fact that there is rather rapid transition from summer to winter and vice versa. When monthly means are used, instead of daily, a third mode due to spring and fall appears, but this is only a feature of the method of computation and daily data should be used in place of monthly when practicable. The dual mode in the range of monthly maximum temperature is probably a snow cover and humidity effect. The dominant mode, 32°, corresponds to the mode for monthly range of minimum temperature, 31°.

Figure 8 shows how histograms of monthly temperature and precipitation, which are very easily prepared from the station annual summaries, although of different nature from histograms made with the daily data, are useful in comparing climates with respect to the general features of rainfall and temperature.

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TEMPERATURE VARIATIONS IN THE UNITED STATES AND ELSEWHERE.

551.524 : 551.501

By ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, D. C., February, 1921.]

SYNOPSIS.

In the first part of the paper effort is made to discover to what extent periods of abnormally high or abnormally low temperature in the United States synchronize and also as to whether or not there is evidence of a periodicity in the occurrence and recurrence of these phenomena. The basic material for the study was 12-month consecutive or overlapping monthly means of the temperature for fairly large geographic districts. The districts used are (1) the New England States, (2) Minnesota, (3) Colorado, (4) Washington, and (5) Louisiana. The monthly mean temperature for each of these districts was originally computed from the means of all of the individual stations therein. The period 1888–1919 furnished the data for the study.

As was to have been expected, the control of the changes in temperature of the various parts of the United States is clearly that of the general circulation of the atmosphere, as modified, of course, by the secondary circulation due to the movement of cyclones and anticyclones.

In order to get beyond the influence of the latter the study was extended to include certain tropical stations, viz, Batavia, Habana, Honolulu, and Arequipa. Consecutive means were also computed for these stations.

Both tropical and temperate zone stations show very clearly the persistence of short-period variations of about 40 months in length; occasionally, for reasons not understood, some of these short-period maxima and minima are greatly intensified and consequently appear as primary maxima or minima in the series. The length of the interval between these so-called primary maxima and minima is greater than and probably some multiple of the 40-month period.

One of the chief characteristics of the data is the tendency of any marked variation in the temperature to be followed by another one of

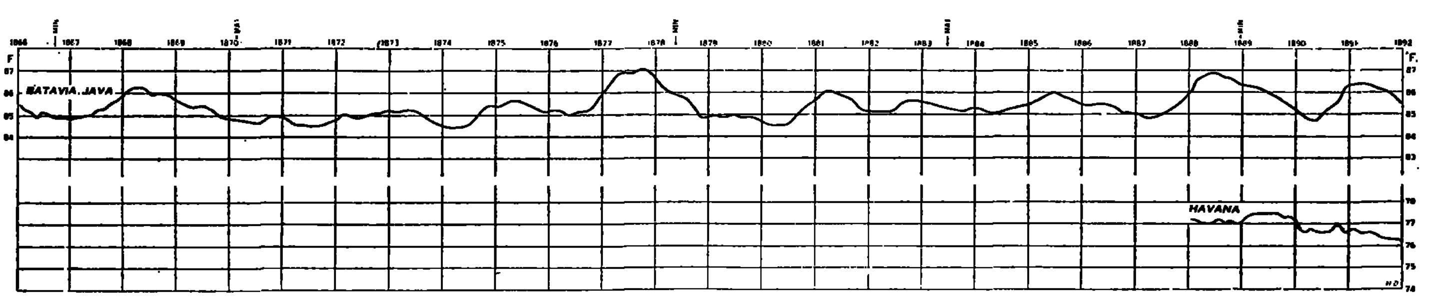

FIG. 1.—Smoothed temperature means, each